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(58) Field of search

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(54) **Heat exchanger**

(57) A heat exchanger (10) consists of a bundle of close-packed parallel tubes (12). Each tube is of elliptical external shape, the orientation of the ellipse varying helically along its length. At successive spaced locations along their length the tubes (12) therefore contact each other; by virtue of these spaced points of contact the tubes (12) are held at fixed separations from each other along most of their length. The tubes (12) might be fuel rods of a nuclear reactor, and might be formed of a refractory metal such as molybdenum.

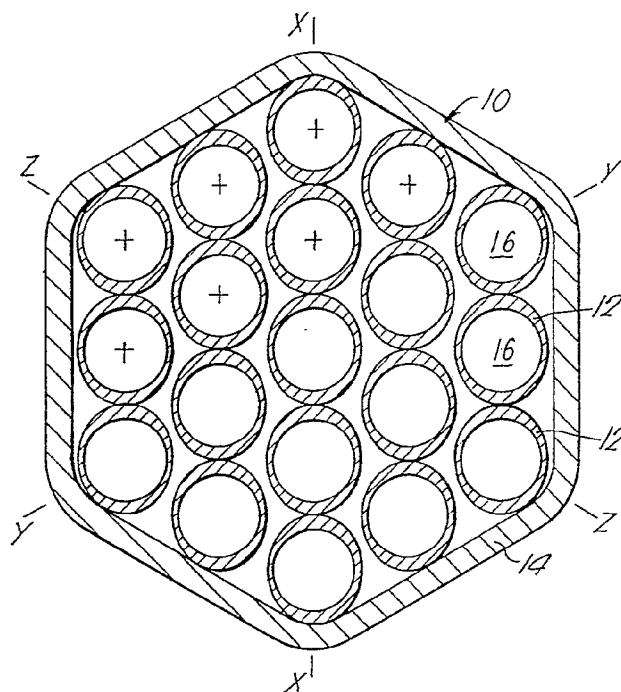


Fig.1.

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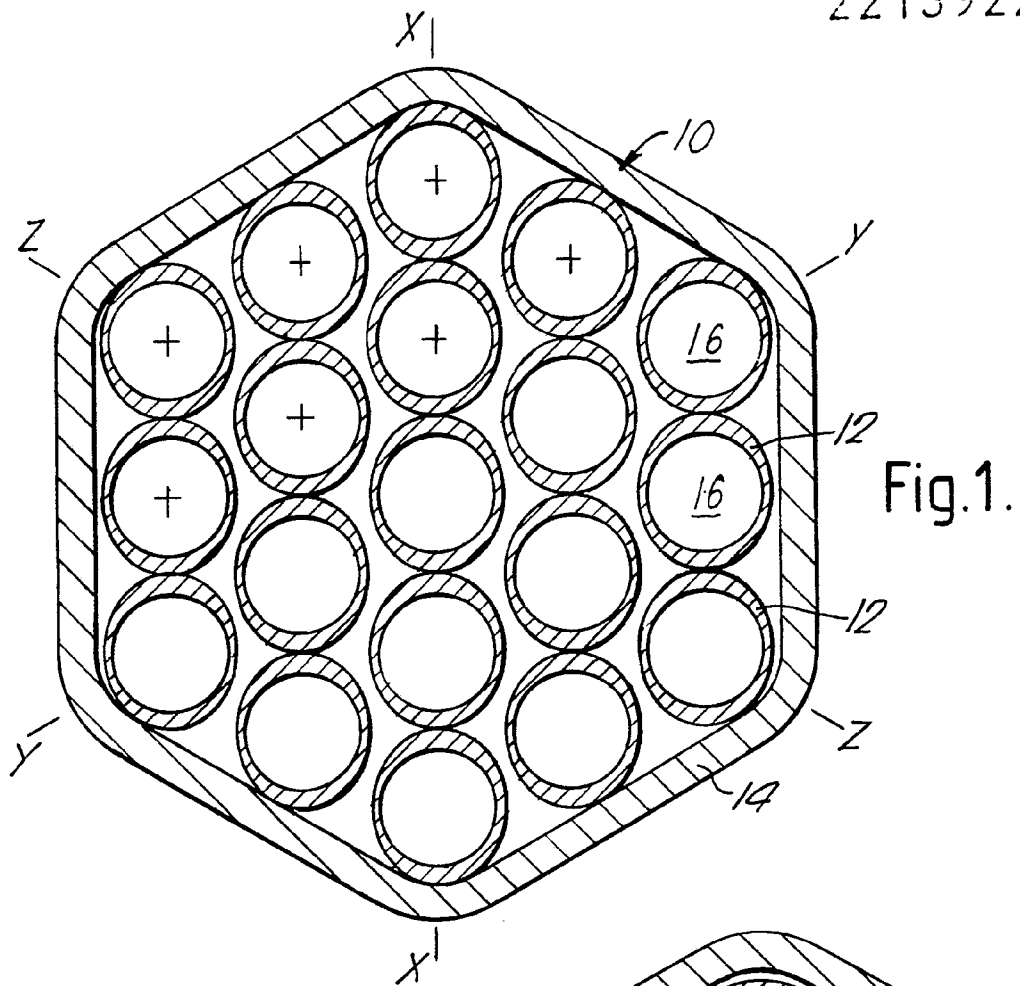


Fig. 1.

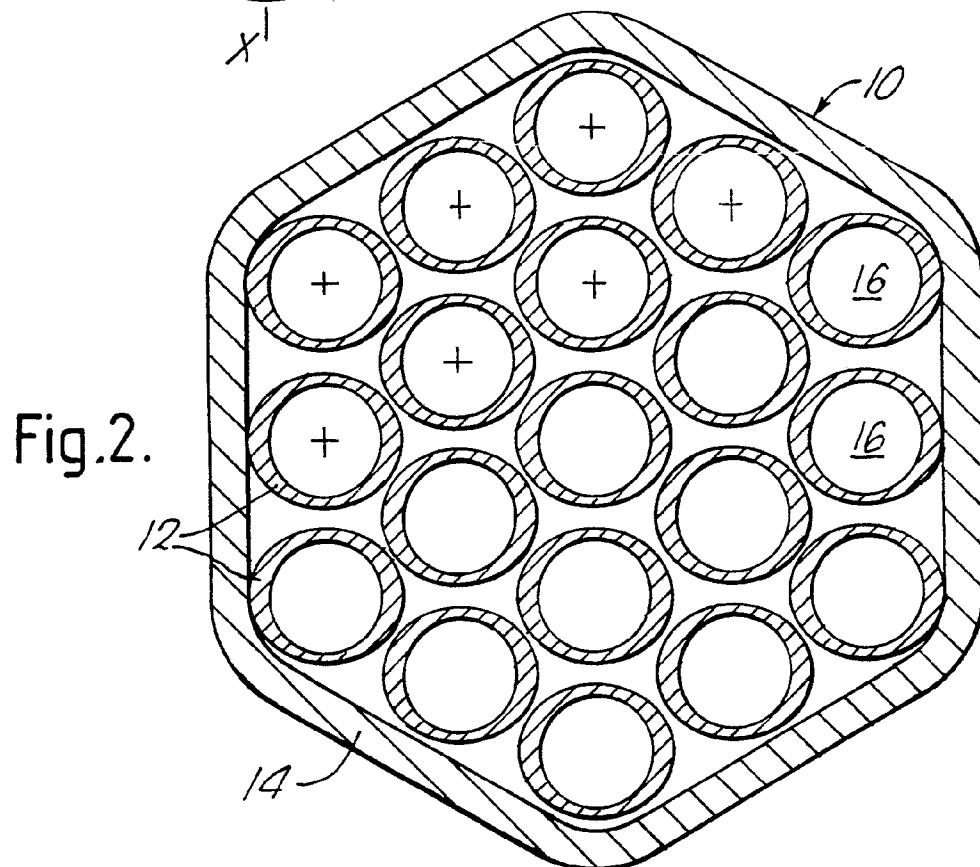


Fig. 2.

Heat Exchanger

This invention relates to a heat exchanger, in particular a heat exchanger including a plurality of
5 parallel tubes for heat transfer between contents of the tubes and a fluid flowing around the tubes.

Tube-in-shell heat exchangers consisting of a large number of parallel tubes within an enclosing shell are well
10 known, one being described in GB 1 438 649 for example. Such heat exchangers, with the tubes extending the entire length of the shell between perforated end plates of the shell, are often used for heat transfer between two fluids, with one fluid flowing along inside the tubes and the other
15 fluid flowing in the shell around the outside of the tubes. Finned tubes for such a heat exchanger are described for example in GB 748 030. Another similar heat exchanger, but with the tubes closed at each end and extending to neither end of the shell, is used in for example a liquid-metal
20 cooled fast reactor core; in this case the tube contents are solid and generate heat as a result of nuclear fission, the heat being transferred to the liquid metal outside the tubes. For example GB 1 416 703 describes a fuel element subassembly for such a core, in which cylindrical elements
25 are spaced apart by helical wire wrappings which act as fins. However where it is desired to make a heat exchanger with tubes of a refractory metal such as molybdenum, and where the tube spacing has to be held at a well-defined but small value, it is difficult to manufacture finned tubes or
30 to weld a wire onto the tube. Such refractory metals are difficult to fabricate, tending to be brittle at room temperature.

According to the present invention there is provided a
35 heat exchanger comprising a plurality of tubes each with a longitudinal axis, at least some of the tubes having a

non-circular external cross-sectional shape the same at all points along the length of a tube, the said shape having a radius measured from said axis varying smoothly around its periphery with at least one maximum value, and the said
5 shape changing in orientation along the length of each tube so that positions of maximum radius in successive cross-sections define a helical path around the longitudinal axis of the tube, all the tubes in the heat exchanger being parallel, and being arranged such that
10 neighbouring tubes contact each other at successive spaced locations along their length.

Preferably all the tubes have the said non-circular external cross-sectional shape. The number of positions
15 around the periphery at which the radius is a maximum might be one (giving an egg-shape), two (giving an elliptical shape), three, or even more; in the preferred embodiment the shape is elliptical.

20 The tubes may have any desired internal cross-sectional shape, which may differ from the external shape, and might for example be circular.

The invention will now be further described by way of
25 example only and with reference to the accompanying drawings, in which:

Figure 1 shows a cross-sectional view through a tube
bundle; and

30

Figure 2 shows another cross-sectional view of the same tube bundle at a different position along its length.

35 Referring to Figure 1 there is shown a cross-sectional view through a tube bundle 10 forming part of a nuclear reactor core. The bundle 10 consists of nineteen identical fuel rods or tubes 12 enclosed in a hexagonal wrapper 14 of

thickness 1.25 mm. Each rod or tube 12 has a circular bore 16 of diameter 4.5 mm containing fissile material (not shown) and during operation heat is transferred through the walls of the tubes 12 from the fissile material to a
5 coolant fluid, for example a pressurised gas, flowing in the spaces between the tubes 12. The longitudinal axes of the tubes 12 extend parallel to each other, forming a regular hexagonal lattice (indicated by plus signs for some of the tubes 12) with equal spacings of 5.5 mm between axes
10 of adjacent tubes 12. Each tube 12 is 600 mm long.

The tubes 12 are of molybdenum and are manufactured by an extrusion process. The external cross-sectional shape is elliptical, with a major axis of length 5.5 mm and a
15 minor axis of length 5.0 mm; since the bore 16 is circular, the wall thickness consequently ranges between 0.25 mm and 0.5 mm. At any position along the length of the bundle 10 the major axes of the ellipses are all parallel to each other, and in the position shown in Figure 1 all the major
20 axes are parallel to the plane X-X. The orientations of the major and minor axes change along the length of each tube 12, following helical paths. Figure 1 shows their orientation at one end of the bundle 10; over the entire length of the bundle 10 the orientation of the ellipses
25 undergoes one complete revolution, so that the tubes 12 would appear as shown in Figure 1 also half-way along the bundle 10 (after a rotation through 180°), and also at the other end of the bundle 10. The tubes 12 contact each other along lines parallel to X-X in Figure 1; a sixth of
30 the way along the bundle 10 the tubes 12 will again contact each other, but along lines parallel to Y-Y as the orientation of each ellipse differs from that of Figure 1 by 60° ; a sixth of the way further along the bundle 10 the tubes 12 will again contact each other, along lines
35 parallel to Z-Z.

Figure 2 shows the tube bundle 10 in section at a position a quarter of the way along its length from one end or the other. Each ellipse is oriented at 90° to the orientation at the end shown in Figure 1, and consequently the tubes 12 do not contact each other. The gaps between adjacent tubes 12 at their narrowest are 0.5 mm in directions parallel to X-X, and about 0.14 mm in directions parallel to Y-Y and to Z-Z.

Thus for much of the length of the tube bundle 10 the tubes 12 do not contact each other at all, yet they are held at fixed separations from each other by contacting adjacent tubes 12 at several spaced positions along their length, successive contact positions corresponding to a difference in orientation of the ellipse axes of 60° . For the bundle 10 described here, of length 600 mm within which the orientation changes by one revolution, the contact positions therefore occur at 100 mm separations along the length.

It will be appreciated that a heat exchanger may differ from that described in relation to Figures 1 and while remaining within the scope of the present invention. For example the dimensions of the tubes may differ, as may the number of rotations of the ellipse axes along their length, which need not be an integer. Furthermore the tubes might be arranged with their axes on a square lattice rather than a hexagonal lattice. Yet again the tube bundle might form part of a tube-in-shell, fluid/fluid, heat exchanger instead of a reactor core; in this case it will be appreciated that the tubes would engage in corresponding holes in tube plates at each end of the heat exchanger shell.

It will also be understood that in the tube bundle 10 shown in the Figures, some of the tubes 12 could be

replaced by cylindrical tubes (not shown) of diameter 5.5 mm. Such a cylindrical tube should preferably be surrounded by six of the elliptical tubes 12, to avoid affecting the rigidity of the tube bundle 10. This does
5 however reduce the space available for fluid flow between tubes.

Claims

1. A heat exchanger comprising a plurality of tubes each with a longitudinal axis, at least some of the tubes having
5 a non-circular external cross-sectional shape the same at all points along the length of a tube, the said shape having a radius measured from said axis varying smoothly around its periphery with at least one maximum value, and the said shape changing in orientation along the length of
10 each tube so that positions of maximum radius in successive cross-sections define a helical path around the longitudinal axis of the tube, all the tubes in the heat exchanger being parallel, and being arranged such that neighbouring tubes contact each other at successive spaced
15 locations along their length.
2. A heat exchanger as claimed in Claim 1 wherein all the tubes have the said non-circular external cross-sectional shape.
20
3. A heat exchanger as claimed in Claim 1 or Claim 2 wherein the said external cross-sectional shape is elliptical.
- 25 4. A heat exchanger as claimed in any one of the preceding Claims wherein the internal cross-sectional shape of each tube is circular.
5. A heat exchanger as claimed in any one of the
30 preceding Claims wherein each tube comprises a refractory metal.
6. A heat exchanger as claimed in any one of the preceding Claims forming a core of a nuclear reactor, each
35 tube having both its ends sealed and enclosing a nuclear fuel material.

7. A heat exchanger as claimed in any one of Claims 1 to 5 wherein each end of each tube communicates with header means whereby a fluid may be caused to flow through the tubes.

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8. A heat exchanger substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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